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(54) **APPARATUS FOR AND METHOD OF FORMING IMAGE**

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CPC ***G03G 15/0803*** (2013.01)

(58) **Field of Classification Search**
CPC G03G 15/0803
USPC 399/265, 266
See application file for complete search history.

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(57) **ABSTRACT**

An apparatus for and method of forming images. The apparatus includes a photosensitive member, a charging member configured to electrify a surface of the photosensitive member to a predetermined electric potential, an exposure member configured to form an electrostatic latent image on the electrified surface of the photosensitive member, and a developing member configured to develop a toner image on the surface of the photosensitive member on which the electrostatic latent image is formed. The developing member converts a toner disposed near the photosensitive member into a cloud state using ultrasonic oscillation and adheres the cloud-state toner to the electrostatic latent image due to a bias voltage applied between the developing member and the photosensitive member.

26 Claims, 5 Drawing Sheets

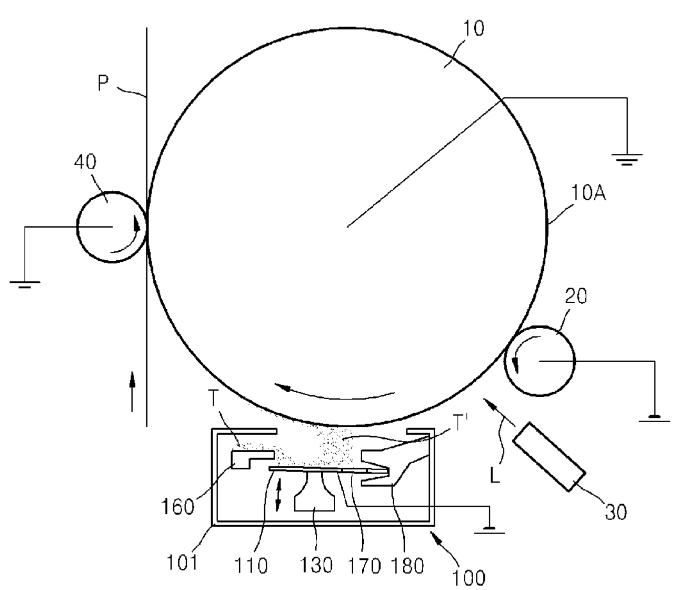


FIG. 1

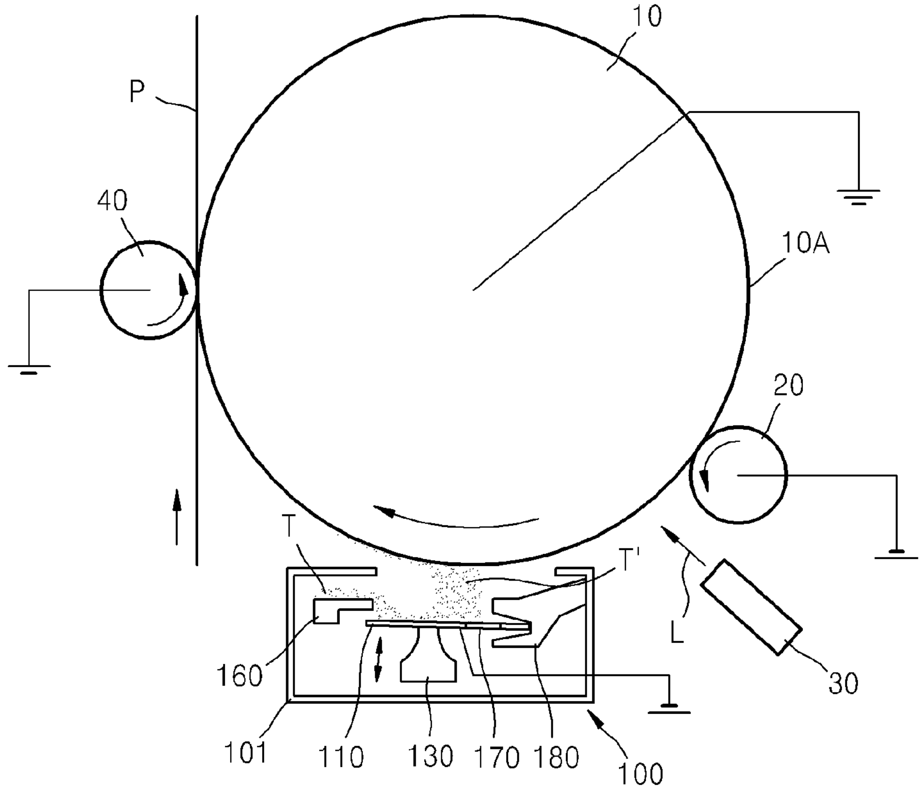

10
P
40
10A
20
T
T'
L
160
30
101
110
130
170
180
100

FIG. 2

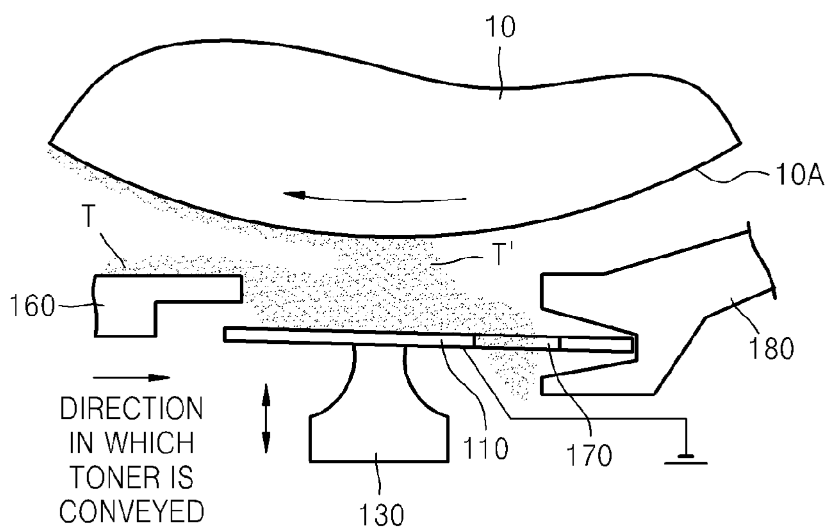

10
10A
T
T'
160
180
DIRECTION IN WHICH TONER IS CONVEYED
110
170
130

FIG. 3A

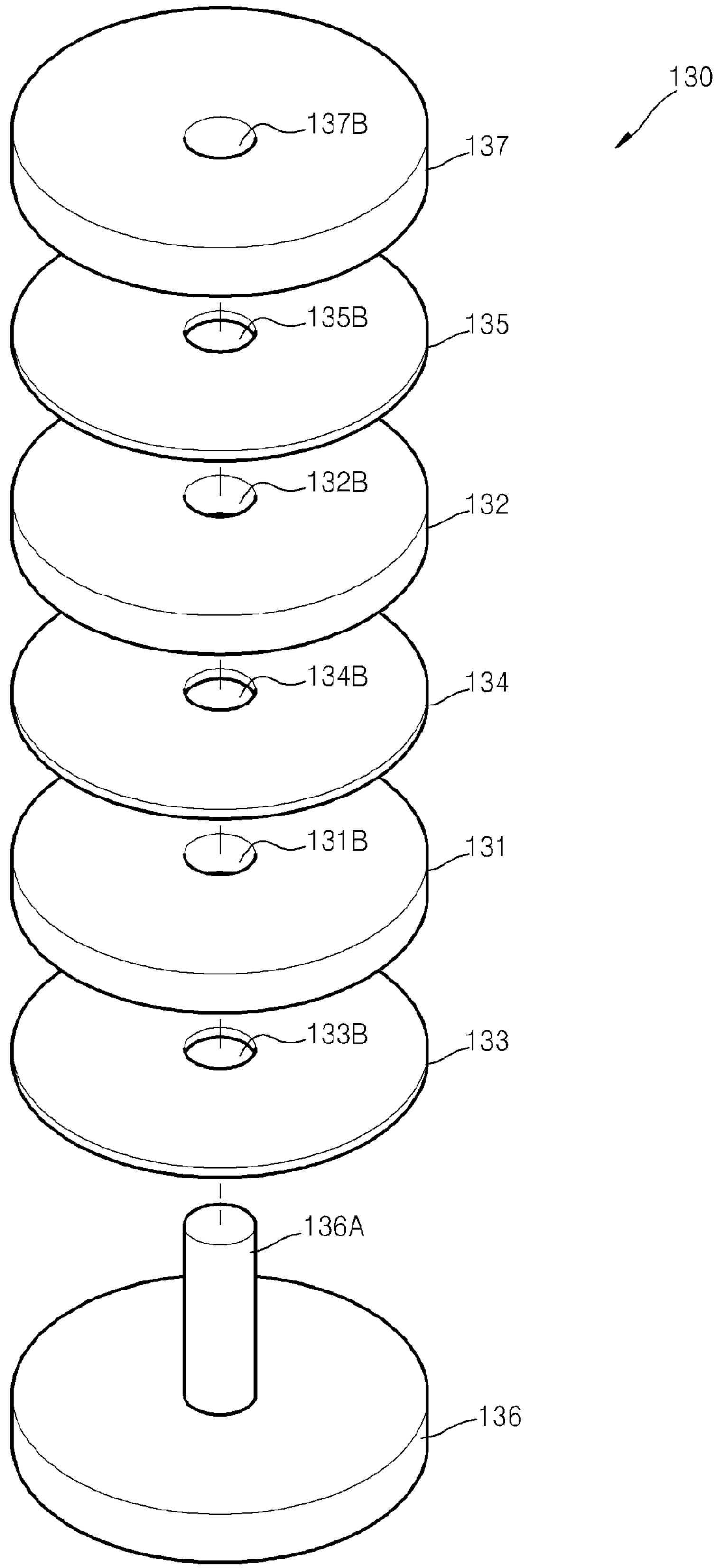

130
137B
137
135B
135
132B
132
134B
134
131B
131
133B
133
136A
136

FIG. 3B

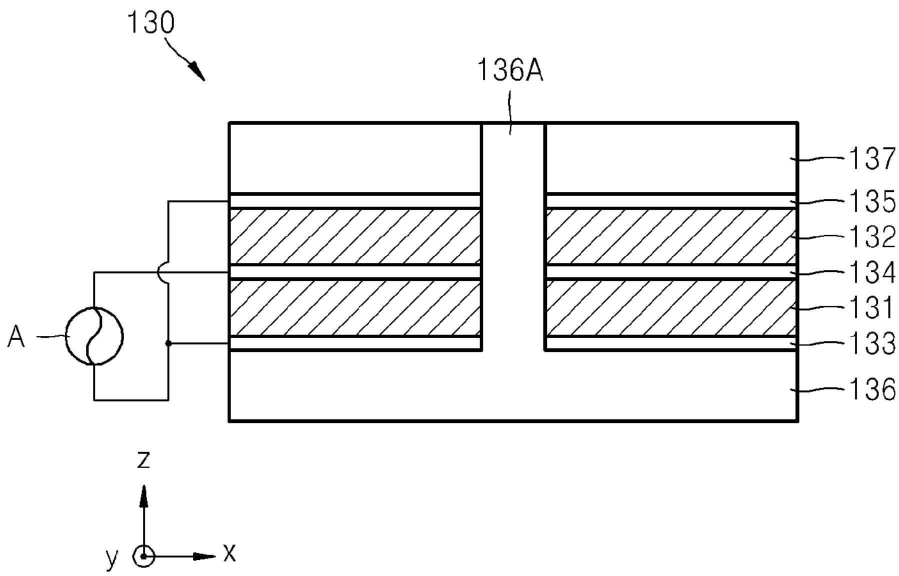

130
136A
137
135
132
134
131
133
136
A
z
y
x

FIG. 4A

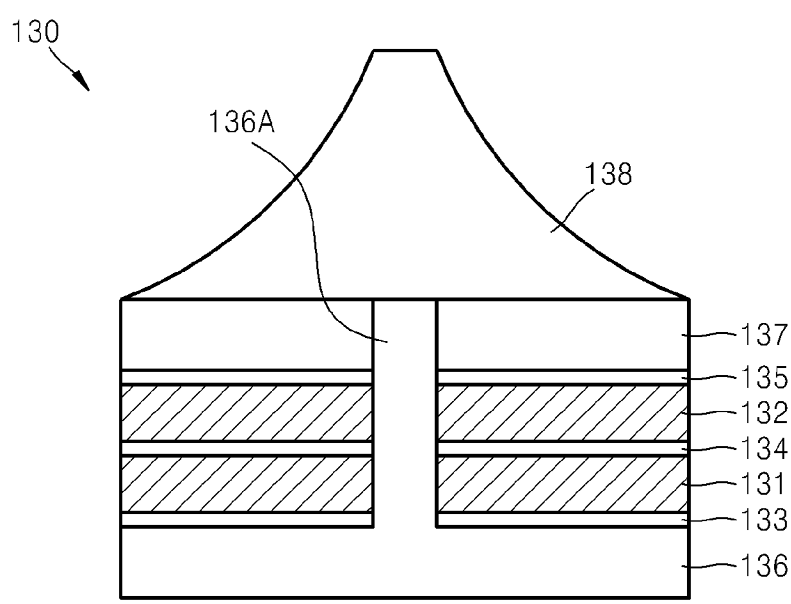

130
136A
138
137
135
132
134
131
133
136

FIG. 4B

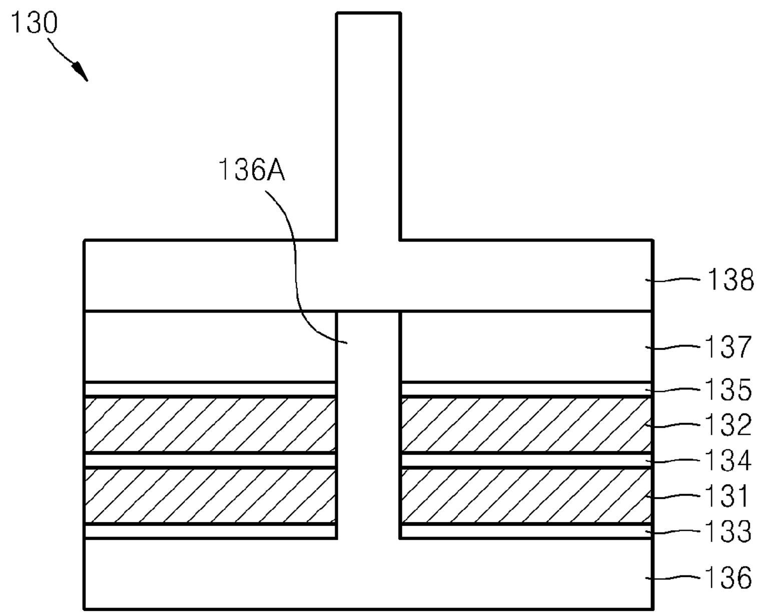

130
136A
138'
137
135
132
134
131
133
136

FIG. 5

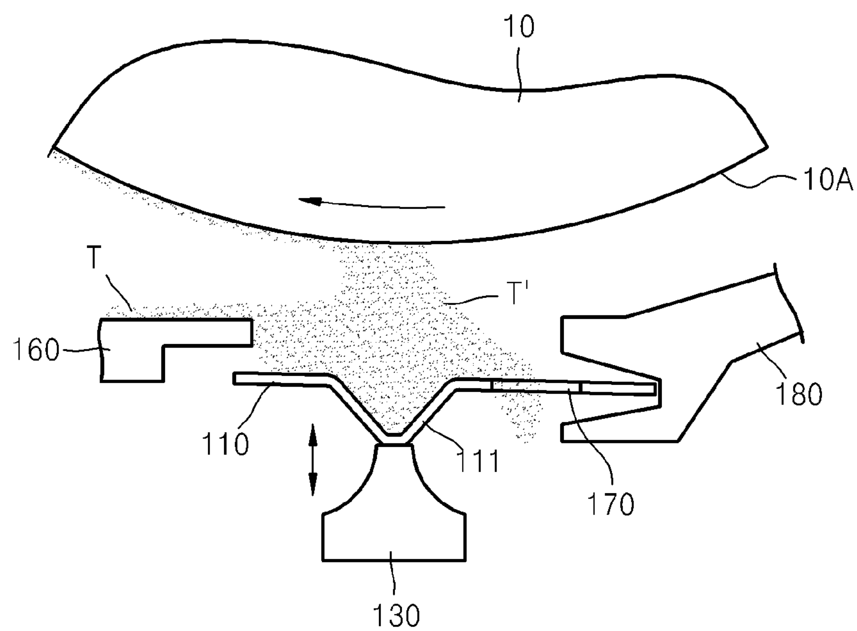
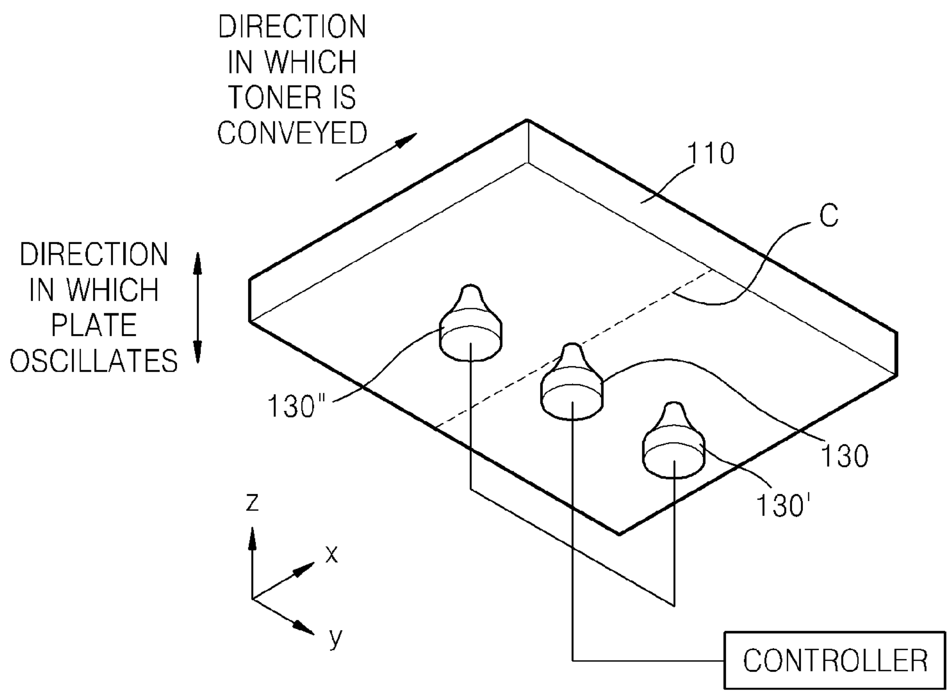

10
10A
T
T'
160
110
111
170
180
130

FIG. 6


DIRECTION
IN WHICH
TONER IS
CONVEYED
DIRECTION
IN WHICH
PLATE
OSCILLATES
110
C
130"
130
130'
z
x
y
CONTROLLER

APPARATUS FOR AND METHOD OF FORMING IMAGE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the priority benefit of Korean Patent Application No. 10-2012-0075748, filed on Jul. 11, 2012, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

The present general inventive concept relates to an apparatus for and method of forming images and, more particularly, to an apparatus for and method of forming images, which may improve a developing member configured to develop a toner image.

2. Description of the Related Art

Image forming apparatuses configured to form images on a recording medium may include printers, photocopiers, fax machines, and multifunctional copiers/printers into which functions thereof are integrated. An image forming apparatus, particularly, an electrophotographic image forming apparatus, may form electrostatic latent images on a photosensitive member and develop the electrostatic latent images using a developing agent, such as a toner, to form images.

In recent years, research has been conducted into a contactless developing technique of forming high-quality images using a simple configuration. A conventional contactless developing technique includes converting a toner into a cloud state by inducing discharge due to electric energy applied to an wire electrode disposed apart from a donor roller configured to convey the toner.

However, when the toner is converted into the cloud state using the wire electrode, the density of clouds may be non-uniform due to the use of an electrode wire with a small diameter, thereby causing image failures, such as image banding and blur. Also, when the donor roller is used, part of the toner may remain on the donor roller after a developing process, thereby causing image failures, such as a ghost phenomenon. Furthermore, since the natural frequency of the electrode wire is within an audio-frequency range of 2 kHz or less, noise may occur. Also, due to long-term application of a high tension to the electrode wire, the endurance of an image forming apparatus may be degraded. For example, the electrode wire may be cut.

SUMMARY

Additional aspects and/or advantages will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the invention.

The present general inventive concept provides an apparatus for and method of forming images using a new technique, which may use an element configured to transduce electric energy into mechanical energy and convert a toner into a cloud state to develop images.

According to an aspect of the present general inventive concept, there is provided an image forming apparatus including a photosensitive member, a charging member configured to electrify a surface of the photosensitive member to a predetermined electric potential, an exposure member configured to form an electrostatic latent image on the electrified surface of the photosensitive member, and a developing member configured to develop a toner image on the surface of the photosensitive member on which the electrostatic latent image is formed, wherein the developing member converts a toner disposed near the photosensitive member into a cloud state using ultrasonic oscillation and adheres the cloud-state toner to the electrostatic latent image due to a bias voltage applied between the developing member and the photosensitive member.

The developing member may include a plate disposed opposite the photosensitive member, the plate on which the toner is loaded, and a transduction element connected to the plate and configured to transduce electrical energy into mechanical energy and oscillate the toner loaded on the plate to convert the toner into a cloud state.

The transduction element may be an ultrasonic transducer having an oscillation frequency of about 15 kHz to about 60 kHz.

The transduction element may be a Langevin-type ultrasonic transducer. The transduction element may include a piezoelectric element, an electrode connected to the piezoelectric element, and oscillation blocks disposed on both top and bottom ends of the piezoelectric element.

A plurality of piezoelectric elements may be provided such that polarization directions of the plurality of piezoelectric elements face one another.

The transduction element may further include a horn configured to amplify oscillation of the piezoelectric element in a thickness direction. The horn may have an exponential sectional shape.

The plate and the transduction element may be fixedly connected by at least one of a bolt connection technique and an adhesive connection technique.

A V-shaped groove may be formed in a top surface of a region of the plate connected to the transduction element.

The plate may be inclined downward along a direction in which the toner is conveyed. The plate may be inclined at an angle of about 50° or less with respect to a direction perpendicular to a direction of gravity.

A top surface of the plate may have a roughness of 10 μm or less.

The plate may include at least one selected from the group consisting of duralumin, titanium (Ti), aluminum (Al), bronze, stainless steel (SUS), and carbon (C) steel.

A plurality of transduction elements may be provided apart from one another in a direction perpendicular to a direction in which the toner is conveyed. The plurality of transduction elements may be symmetrically disposed with respect to a central line of the plate.

The image forming apparatus may further include a controller connected to the plurality of transduction elements.

According to another aspect of the present general inventive concept, there is provided a method of forming images, including: electrifying a surface of a photosensitive member to a predetermined electric potential, forming an electrostatic latent image on the surface of the photosensitive member, converting a toner disposed near the photosensitive member into a cloud state using ultrasonic oscillation applied by a developing member, and adhering the cloud-state toner to the electrostatic latent image due to a bias voltage applied between the developing member and the photosensitive member.

The conversion of the toner disposed near the photosensitive member into the cloud state may include loading the toner on a plate disposed opposite the photosensitive member, and transducing electric energy into mechanical energy using a transduction element connected to the plate to oscillate the toner loaded on the plate and convert the toner into the cloud state.

The transduction element may be an ultrasonic transducer having an oscillation frequency of about 15 kHz to about 60 kHz.

The transduction element may be a Langevin-type ultrasonic transducer.

A plurality of transduction elements may be provided apart from one another in a direction perpendicular to a direction in which the toner is conveyed.

The plurality of transduction elements may be symmetrically disposed with respect to a central line of the plate.

The plurality of transduction elements may be controlled by a single controller.

According to an apparatus for and method of forming images according to the present general inventive concept, a large amount of toner loaded on a plate can be converted into a cloud state using ultrasonic oscillation. Thus, not only an imaging speed but also image quality can be improved. Also, since ultrasonic oscillation is used, the endurance of the image forming apparatus can increase, and generation of noise can be prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of the present general inventive concept will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

FIG. **1** is a schematic construction diagram of an image forming apparatus according to an embodiment of the present general inventive concept;

FIG. **2** is an enlarged view of a developing member of the image forming apparatus of FIG. **1**, according to an embodiment of the present general inventive concept;

FIG. **3**A is a schematic exploded perspective view of a transduction element of the developing member of FIG. **2**;

FIG. **3**B is a schematic cross-sectional view of the transduction element of the developing member of FIG. **2**;

FIGS. **4**A and **4**B are cross-sectional views of other examples of the transduction element of the image forming apparatus according to the present embodiment;

FIG. **5** illustrates a plate of the image forming apparatus according to the present embodiment; and

FIG. **6** illustrates arrangement of a plurality of transduction elements of the image forming apparatus according to the present embodiment.

DETAILED DESCRIPTION

An apparatus for and method of forming images according to the present general inventive concept will now be described more fully with reference to the accompanying drawings, in which exemplary embodiments of the present general inventive concept are shown. As used herein, expressions such as “at least one of,” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

FIG. **1** is a schematic construction diagram of an image forming apparatus according to an embodiment of the present general inventive concept. Referring to FIG. **1**, the image forming apparatus may include a photosensitive member **10**, a charging member **20**, an exposure member **30**, and a developing member **100**.

Before describing specific features of the present general inventive concept, a process of forming an image on a recording medium will briefly be explained.

To form a desired image on a recording medium P, an image forming apparatus forms an electrostatic latent image corresponding to the desired image on a surface **10**A of the photosensitive member **10** and adhere a cloud-state toner T' (hereinafter, referred to as a ‘toner cloud’) to the electrostatic latent image to form a toner image corresponding to the electrostatic latent image.

To form the electrostatic latent image, the surface **10**A of the photosensitive member **10** may be electrified to a predetermined electric potential by the charging member **20**. A predetermined charging bias voltage of, for example, about −700V to about −800V, may be applied to the charging member **20**. A charging roller or a corona charger may be adopted as the charging member **20**. In this case, a different voltage from the voltage applied to the surface **10**A, for example, a ground voltage GND of 0V, may be applied to the photosensitive member **10**.

Modulated light L corresponding to image information may be irradiated by the exposure member **30** to the electrified surface **10**A of the photosensitive member **10**. A region of the surface **10**A of the photosensitive member **10** to which the light L is irradiated may have a varied surface potential. For example, when the surface **10**A of the photosensitive member **10** is electrified to a potential of about −700V to −800V, a surface potential of the region irradiated with the light L may be reduced to about −50V to about −100V. By varying the surface potential of the region irradiated with the light L, an electrostatic latent image may be formed. In this case, the exposure member **30** may be a light-emitting diode (LED)-type exposure unit capable of selectively allowing a plurality of LEDs arranged in a main scan direction to emit light. Alternatively, the exposure member **30** may be a laser scanning unit (LSU) capable of deflecting light irradiated by a laser diode (LD) in the main scan direction using a light deflector, and scanning the deflected light to the surface **10**A of the photosensitive member **10**.

The developing member **100** may supply a toner cloud T to the surface **10**A of the photosensitive member **10** on which the electrostatic latent image is formed, and develop a toner image corresponding to image information.

The present embodiment pertains to a contactless technique in which the toner T is conveyed by conveying unit **160** is converted into the cloud state and the toner cloud T' is supplied to the surface **10**A of the photosensitive member **10** to form a highly uniform image.

Here, by applying a bias voltage between the developing member **100** and the photosensitive member **10**, the toner cloud T' may move to the surface **10**A of the photosensitive member **10**. In this case, although not shown, the toner T may remain charged with substantially the same polarity as the surface **10**A of the photosensitive member **10**, for example, negative (−) polarity. Similarly, the toner cloud T' obtained by converting the toner T into the cloud state may remain charged with substantially the same polarity as the surface **10**A of the photosensitive member **10**. Thus, the toner cloud T' may be adhered to the electrostatic latent image, which is a region having a different surface potential from the surface **10**A of the photosensitive member **10**, to form a toner image.

The toner image may be adhered to one surface of the recording medium P supplied between the photosensitive member **10** and a transfer member **40**. In this case, a predetermined bias voltage having an opposite polarity to the toner image may be applied to the transfer member **40**. Although FIG. **1** pertains to an example in which the photosensitive member **10** is in direct contact with the recording medium P, the present general inventive concept is not limited thereto, and an intermediate transfer belt (ITB) may be disposed between the photosensitive member **10** and the transfer member **40**.

Although not shown, the image forming apparatus may include a paper supply unit (not shown) configured to supply the recording medium P, a fusing unit (not shown) configured to fuse the toner image adhered to the recording medium P, and a paper discharge unit (not shown) configured to discharge the fused recording medium P.

FIG. **2** is an enlarged view of the developing member **100** of the image forming apparatus of FIG. **1**, according to an embodiment of the present general inventive concept.

Referring to FIGS. **1** and **2**, the developing member **100** according to the present embodiment may use ultrasonic oscillation to convert the toner T into a cloud state. Specifically, a technique of converting the toner T into the cloud state using ultrasonic oscillation may include converting the toner T into the cloud state using oscillation caused by transducing electric energy into mechanical energy. Since this technique is absolutely different from a conventional technique of converting a toner into a cloud state using discharge and does not require a donor roller, image failures (e.g., ghost) caused by the use of the donor roller may be prevented. Also, since an oscillation frequency belonging to an ultrasonic region is used, noise may be eliminated.

To employ ultrasonic oscillation, the developing member **100** may include a housing **101**, a transduction element **130** configured to transduce electric energy into mechanical energy and a plate **110** connected to the transduction element **130** and capable of loading the toner T.

The transduction element **130** may receive alternating-current (AC) power from an external power supply and cause oscillation, which is repetition of mechanical movements (i.e., compression and expansion). The oscillation may be transmitted to the plate **110** connected to the transduction element **130**. Due to the plate **110** that oscillates along with the transduction element **130**, the toner T loaded on the plate **110** may be converted into the cloud state.

The transduction element **130** serving as an ultrasonic oscillator may have an oscillation frequency of about 15 kHz to about 60 kHz. Since most of the oscillation frequency of the transduction element **130** departs from an audio frequency, generation of noise may be reduced as compared with the conventional case in which a toner is converted into a cloud state using discharge.

FIG. **3**A is a schematic exploded perspective view of the transduction element **130** of the developing member of FIG. **2**, and FIG. **3**B is a schematic cross-sectional view of the transduction element of the developing member of FIG. **2**.

A Langevin-type ultrasonic transducer may be used as the transduction element **130**. The Langevin-type ultrasonic transducer may protect piezoelectric elements **131** and **132**, which are vulnerable to strain, and obtain more stable outputs.

As shown in FIGS. **3**A and **3**B, the transduction element **130** may include the piezoelectric elements **131** and **132**, electrodes **133**, **134**, and **135** connected to the piezoelectric elements **131** and **132**, and oscillation blocks **136** and **137** disposed on both top and bottom ends of the piezoelectric elements **131** and **132**. The piezoelectric elements **131** and **132**, the electrodes **133**, **134**, and **135**, and the oscillation blocks **136** and **137** may be fixed by a bolt **136**A. The piezoelectric elements **131** and **132**, the electrodes **133**, **134**, and **135**, and the oscillation blocks **136** and **137** may have holes **131**B-**136**B, respectively, which corresponds to the shape of a bolt **136**A. However, the oscillation block **137** may not have a hole only one side portion thereof to be fixed with the bolt **136**A. Here, although FIGS. **3**A and **3**B show an example in which the bolt **136**A is integrally formed with the oscillation block **136**, the bolt **136**A may be a separate member from the oscillation block **136**.

The piezoelectric elements **131** and **132** connected to the electrodes **133**, **134**, and **135** may convert electric signals into oscillation. Resonance frequencies of the piezoelectric elements **131** and **132** may linearly increase by force for compressing the piezoelectric elements **131** and **132** in a thickness direction. Also, as a voltage applied to the piezoelectric elements **131** and **132** increases, the amplitude of the piezoelectric elements **131** and **132** may linearly increase.

A plurality of piezoelectric elements **131** and **132** may be provided. When the plurality of piezoelectric elements **131** and **132** are connected, each of pairs of piezoelectric elements **131** and **132** may be disposed such that polarization directions thereof face each other. When the polarization directions of each of the pairs of piezoelectric elements **131** and **132** face each other, as shown in FIG. **3**B, the same electrode **134** may be connected to a bottom surface of the piezoelectric element **132** disposed above and a top surface of the piezoelectric element **131** disposed below. Thus, the oscillations of the plurality of piezoelectric elements **131** and **132** may be prevented from counterbalancing one another using a relatively simple structure. Here, the electrodes **133**, **134**, and **135** may be formed of phosphor bronze or beryllium (Be).

The oscillation blocks **136** and **137** may include a first oscillation block **137** disposed on the top end of the piezoelectric element **132** and a second oscillation block **136** disposed on the bottom end of the piezoelectric element **131**.

The first oscillation block **137** may function to amplify the amplitude of oscillation, which is caused by the piezoelectric elements **131** and **132** in the thickness direction. The second oscillation block **136** may function to reflect a downward wavelength of oscillation caused in upward and downward directions of the piezoelectric elements **131** and **132** and add the reflected wavelength to upward wavelength. To this end, the second oscillation block **136** may have a lower acoustic impedance than the piezoelectric elements **131** and **132**. Also, the second oscillation block **136** may function to absorb and cool off heat generated by the transduction element **130**.

A length of the transduction element **130** may be set to about a half of an oscillation wavelength of the transduction element **130** or about equal to the oscillation wavelength thereof. Thus, breakage of the transduction element **130** may be prevented while setting the amplitude to a great value.

By adopting the Langevin-type ultrasonic transducer as the transduction element **130**, a natural oscillation frequency higher than the natural oscillation frequencies of the piezoelectric elements **131** and **132** may be embodied.

FIG. **4**A is a cross-sectional view of another example of the transduction element **130** of the image forming apparatus according to the present embodiment. Referring to FIG. **4**A, the transduction element **130** may further include a horn **138** to amplify the oscillation of the piezoelectric elements **131** and **132** in a thickness direction. The horn **138** may amplify the oscillation of the piezoelectric elements **131** and **132** to satisfy an amplitude of about several hundred μm to several mm without affecting the oscillation frequency of the transduction element **130**.

The horn **138** may be connected to the first oscillation block **137**. The horn **138** connected to the first oscillation block **137** may concentrate oscillation received through the first oscillation block **137** on an end portion of the horn **138** having a small area, and amplify the oscillation of the piezoelectric elements **131** and **132**.

The horn **138** may be formed in various shapes in consideration of a disposition space or adjustment of oscillation power. For example, the horn **138** may be an exponential horn whose sectional shape varies exponentially as shown in FIG. **4**A. Since a ratio of an oscillation speed of a top end of the exponential horn to an oscillation speed of a bottom end thereof is equal to a ratio of a diameter of the top end of the exponential horn to a diameter of the bottom end thereof, a desired oscillation speed may be embodied by controlling the diameter ratio. In another example, the horn **138** may be replaced by a stepped horn **138'** as shown in FIG. **4**B or a hybrid horn.

Referring back to FIG. **2**, the plate **110** may be disposed opposite the photosensitive member **10**, and the toner T may be loaded on the plate **110**. The plate **110** may be connected to the foregoing transduction element **130**, for example, to a top end portion of the transduction element **130**. Thus, the plate **110** connected to the transduction element **130** may convert the toner T, which is disposed near the photosensitive member **10** disposed on the plate **110**, into a cloud state due to oscillation received by the transduction element **130**.

By fixedly connecting the plate **110** with the transduction element **130**, oscillation of the transduction element **130** may be stably transmitted to the plate **110**, and noise caused by collision of the plate **110** with the transduction element **130** may be prevented. The plate **110** and the transduction element **130** may be fixedly connected using at least one of a bolt connection technique and an adhesive connection technique. In an example of the adhesive connection technique, an adhesion method using epoxy resin may be employed.

To ensure a sufficient amount of toner cloud T', a V-shaped groove **111** formed in a top portion of the plate **110**, which is connected to the transduction element **130** as shown in FIG. **5**. Thus, a Neumann effect may be used. The Neumann effect refers to the focusing of oscillation received by the transduction element **130** in one direction to maximize the oscillation.

The plate **110** may convert the toner T into a cloud state and return the remaining toner T, except for the toner cloud T', to an exhaust unit **170**. The exhaust unit **170** may be formed in the plate **110** or formed between the plate **110** and a support unit **180** configured to support the plate **110**. To return the remaining toner T, except for the toner cloud T', to the exhaust unit **170**, the plate **110** may be inclined downward along a direction in which the toner T is conveyed. For example, the plate **110** may be disposed such that an upstream side of the direction in which the toner T is conveyed is lower than a downstream side thereof. By inclining the plate **110** downward, gravity may act on the toner T loaded on the plate **110** so that the toner T can be easily retrieved. For instance, the plate **110** may be inclined at an angle of about 50° or less with respect to a horizontal direction perpendicular to the direction of gravity.

In addition, to reduce a load of the toner T caused by a relationship between the toner T and the plate **110** during the conveyance of the toner T loaded on the plate **110**, a surface of the plate **110** may include a mirror surface. In an example, the plate **110** may have a surface roughness of about 10 μm or less.

A width of the plate **110** may be greater than a maximum width of the recording medium P used for the image forming apparatus. For instance, when the recording medium P has a maximum width of about A3 (297 mm), the width of the plate **110** may exceed about 297 mm.

The plate **110** may be formed of at least one material selected from the group consisting of duralumin, titanium (Ti), aluminum (Al), brass, stainless steel (SUS), and carbon (C) steel.

Furthermore, the plate **110** may be electrified to a predetermined electric potential. For example, the plate **110** may be electrified to about −200V to about −400V. In this case, when a ground voltage of 0V is applied to the photosensitive member **10**, a bias voltage may be formed between the plate **110** and the photosensitive member **10** and induce the toner cloud T' to move to the surface **10**A of the photosensitive member **10**. Also, since the plate **110** has the same polarity as the toner T loaded on the plate **100**, adhesion of the toner T to the surface of the plate **110** may be prevented.

Meanwhile, the number of transduction elements **130** fixedly connected to the plate **110** may vary according to the shape and size of the plate **110**. In an example, a plurality of transduction elements **130** may be fixedly connected to the plate **110**. The plurality of transduction elements **130** fixedly connected to the plate **110** may transduce the toner T loaded on the plate **110** into a toner cloud T' having a uniform density.

FIG. **6** is a perspective view of arrangement of a plurality of transduction elements of the image forming apparatus according to the present embodiment, which is a bottom view of the plate **110**. As shown in FIG. **6**, a plurality of transduction elements **130**, **130'**, and **130"** may be disposed apart from one another in a direction (Y direction) perpendicular to a direction (X direction) in which the toner T is conveyed. The plurality of transduction elements **130**, **130'**, and **130"** may be symmetrically disposed with respect to a central line C of the plate **110**. Here, the central line C refers to a line connecting the centers of lengths of the plate **110** measured in the direction (Y direction) perpendicular to the direction (X direction) in which the toner T is conveyed.

The plurality of transduction elements **130**, **130'**, and **130"** may be controlled by at least one controller. As a non-limiting example, When a single controller is used to control the plurality of transduction elements **130**, **130'** and **130"**, since oscillation phases of the plurality of transduction elements **130**, **130'**, and **130"** may be synchronized by the single controller, the oscillations of the plurality of transduction elements **130**, **130'**, and **130"** may be prevented from counterbalancing one another.

While the present general inventive concept has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present general inventive concept as defined by the following claims. For example, the above-described embodiment pertains to an image forming apparatus using a monochromatic toner, but the present general inventive concept is not limited thereto. The present general inventive concept also may be applied to an image forming apparatus for forming colored images using color toners such as a cyan (C) toner, a magenta (M) toner, a yellow (Y) toner, and a blank (K) toner.

What is claimed is:

1. An image forming apparatus comprising:

a photosensitive member;

a charging member configured to electrify a surface of the photosensitive member to a predetermined electric potential;

an exposure member configured to form an electrostatic latent image on the electrified surface of the photosensitive member; and a developing member configured to develop a toner image on the surface of the photosensitive member on which the electrostatic latent image is formed;

wherein the developing member converts a toner disposed near the photosensitive member into a cloud state using ultrasonic oscillation and adheres the cloud-state toner to the electrostatic latent image due to a bias voltage applied between the developing member and the photosensitive member,

wherein the developing member includes a plate disposed opposite the photosensitive member, to which plate the toner is conveyed; and

a plurality of transduction elements connected to the plate and configured to transduce electrical energy into mechanical energy and oscillate the toner on the plate to convert the toner into the cloud state,

wherein the plurality of transduction elements are provided apart from one another in a direction perpendicular to a direction in which the toner is conveyed.

2. The apparatus of claim **1**, wherein at least one of the plurality of transduction elements is an ultrasonic transducer having an oscillation frequency of about 15 kHz to about 60 kHz.

3. The apparatus of claim **2**, wherein at least one of the plurality of transduction elements are a Langevin-type ultrasonic transducer.

4. The apparatus of claim **3**, wherein at least one of the plurality of transduction elements comprise:

a piezoelectric element with top and bottom ends;

an electrode connected to the piezoelectric element; and

an oscillation block disposed on both of the top and bottom ends of the piezoelectric element.

5. The apparatus of claim **4**, wherein the piezoelectric element comprises a plurality of piezoelectric elements provided such that polarization directions of the plurality of piezoelectric elements face one another.

6. The apparatus of claim **4**, wherein at least one of the plurality of transduction elements further comprises a horn configured to amplify the oscillation of the piezoelectric element in a thickness direction.

7. The apparatus of claim **6**, wherein the horn has an exponential sectional shape.

8. The apparatus of claim **7**, further comprising a controller connected to the piezoelectric element, wherein the controller controls the oscillation by controlling a diameter ratio of top and bottom ends of the exponential horn.

9. The apparatus of claim **8**, wherein a ratio of the oscillation of the top end of the exponential horn to the oscillation of the bottom end of the exponential horn is equal to a ratio of a diameter of the top end of the exponential horn to a diameter of the bottom end of the exponential horn.

10. The apparatus of claim **4**, wherein the electrode is formed of phosphor bronze or beryllium (BE).

11. The apparatus of claim **1**, wherein the plate and the plurality of transduction elements are fixedly connected by at least one of a bolt and an adhesive.

12. The apparatus of claim **1**, wherein the plate is inclined downward along a direction in which the toner is conveyed.

13. The apparatus of claim **12**, wherein the plate is inclined at an angle of about 50° or less with respect to a direction perpendicular to a direction of gravity.

14. The apparatus of claim **1**, wherein a top surface of the plate has a roughness of 10μm or less.

15. The apparatus of claim **1**, wherein the plate includes at least one selected from the group consisting of duralumin, titanium (Ti), aluminum (Al), bronze, stainless steel (SUS), and carbon (C) steel.

16. The apparatus of claim **1**, wherein the plurality of transduction elements are symmetrically disposed with respect to a central line of the plate.

17. The apparatus of claim **1**, further comprising a controller connected to the plurality of transduction elements.

18. The apparatus of claim **1**, wherein a length of the plurality of transduction elements is about a half of an oscillation wavelength of the plurality of transduction elements.

19. The apparatus of claim **1**, wherein a length of the plurality of transduction elements is about equal to an oscillation wavelength of the plurality of transduction elements.

20. The apparatus of claim **1**, wherein the plate is electrified to a predetermined potential to form the bias voltage between the plate and the photosensitive member to induce the toner in the cloud state to move towards the photosensitive member when a ground voltage is applied to the photosensitive member.

21. An image forming apparatus comprising:

a photosensitive member;

a charging member configured to electrify a surface of the photosensitive member to a predetermined electric potential;

an exposure member configured to form an electrostatic latent image on the electrified surface of the photosensitive member; and

a developing member configured to develop a toner image on the surface of the photosensitive member on which the electrostatic latent image is formed,

wherein the developing member converts a toner disposed near the photosensitive member into a cloud state using ultrasonic oscillation and adheres the cloud-state toner to the electrostatic latent image due to a bias voltage applied between the developing member and the photosensitive member,

wherein the developing member includes a plate disposed opposite the photosensitive member, on which plate the toner is loaded; and

a transduction element connected to the plate and configured to transduce electrical energy into mechanical energy and oscillate the toner on the plate to convert the toner into the cloud state,

wherein a V-shaped groove is formed in a top surface of a region of the plate connected to the transduction element.

22. A method of forming images, comprising:

electrifying a surface of a photosensitive member to a predetermined electric potential;

forming an electrostatic latent image on the surface of the photosensitive member;

converting a toner disposed near the photosensitive member into a cloud state using ultrasonic oscillation applied by a developing member; and

adhering the cloud-state toner to the electrostatic latent image due to a bias voltage applied between the developing member and the photosensitive member,

wherein the converting the toner includes conveying the toner to a plate disposed opposite the photosensitive member, and transducing electric energy into mechanical energy using a plurality of transduction elements connected to the plate to oscillate the toner on the plate and convert the toner into the cloud state, and

wherein the plurality of transduction elements are provided apart from one another in a direction perpendicular to a direction in which the toner is conveyed.

23. The method of claim **22**, wherein at least one of the plurality of transduction elements is selected to be an ultrasonic transducer having an oscillation frequency of about 15 kHz to about 60 kHz.

24. The method of claim **23**, wherein at least one of the plurality of transduction elements is selected to be a Langevin-type ultrasonic transducer.

25. The method of claim **22**, wherein the plurality of transduction elements are symmetrically disposed with respect to a central line of the plate.

26. The method of claim **25**, wherein the plurality of transduction elements are controlled by a single controller.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,057,979 B2
APPLICATION NO. : 13/790233
DATED : June 16, 2015
INVENTOR(S) : Kyung-hwan Kim et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Col. 9, line 63, claim 14, delete “10μm” and insert --10 μm-- therefor.

Signed and Sealed this
Thirteenth Day of October, 2015

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office